Finned Helicoidal Heat Exchanger

Cross-Reference to Related Applications

None.

Statement Regarding Federally Sponsored Research or Development

Not Applicable.

Appendix

Not Applicable.

Background of the Invention

1. Field of the Invention

The present invention relates generally to the field of heat exchangers and, more particularly, to a heat exchanger having helical coils whose performance is improved by the addition of fins.

2. Related Art

Heat exchangers are used to transfer heat between fluids. Many different designs accomplish this, invariably by relying on the basic thermodynamic principle that heat is transferred from a warmer body to a cooler one. One of the more commonly used types of heat exchangers is a fin and tube heat exchanger, such as the evaporator or condenser of a common air conditioner. Separate fin strips are arranged in an array with holes in each to receive perpendicular tubing. One of the working fluids flows through the tubes and a second fluid (such as air) flows on the outside over the fins and tubes. Although fin and tube heat

exchangers provide good thermal contact between the cross-fins and the tubing, a shortcoming is that the tubing must be inserted in sections and the sections interconnected at the ends by return bends which are soldered or otherwise connected to the tube sections. The return bends force the first fluid to turn 180 degrees in each pass thereby causing an excessive pressure drop in the first fluid.

To force the second fluid, which in many cases is air, through the fin spaces and externally across the tubing sections, a fan structure is typically employed. Due to the placement of the fan structure relative to the coil, and because the fans are circular and the heat exchangers rectangular and the respective different areas thereof, it is common for the air velocities to vary substantially over the face of the heat exchanger. This non-uniform air velocity through different portions of the coil often creates a variety of operational problems and inefficiencies in which the coil is incorporated, leading to a lowering the overall heat exchange capability of the coil.

An example of known heat exchangers is provided by U.S. Patent No. 1,785,159 wherein thin ribbons or strips of metal are secured to the outside surface of a pipe to provide it with integral ribs or fins. The pipe is formed into a helical coil. In such heat exchangers, the coil loop radial spacing is limited by the dimensions of the fin which will prevent close spacing of the loops. They also limit the types of fin material that can be used. High pressure applications also are problematic because in known heat exchangers the fins do not strengthen the heat exchanger and, thus, service life is adversely affected.

Summary of the Invention

It is in view of the above problems that the present invention was developed. The invention is a heat exchanger having a plurality of heat transfer tubes arranged substantially in the shape of a helicoidal tube with the individual coils running parallel to one another in a spiral pattern. A plurality of fins are secured to the external surfaces of the heat transfer tubes and extend away therefrom. The first working fluid flows inside the heat transfer tubes, and the second working fluid, typically air, flows through the passages between the adjacent fins and tubes. To further enhance the exchange of thermal energy between the fluids, a blower may be placed inside the coil cavity or around the coil, with blower's blades being parallel to the central coil axis.

The invention incorporates characteristics of high fin density, close coil spacing, and non-uniform fin size. The attachment of the fins to at least two adjacent loops not only enhances the rate of heat transfer, but also provides for enhanced structural strength that allows the use of this design for applications where the first heat exchanging fluid is at elevated pressures. These characteristics and the absence of 180 degree bends result in a significantly more compact heat exchanger having superior heat transfer characteristics.

Further features and advantages of the present invention, as well as the structure and operation of various embodiments of the present invention, are described in detail below with reference to the accompanying drawings.

Brief Description of the Drawings

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate the embodiments of the present invention and together with the description, serve to explain the principles of the invention. In the drawings:

Figures 1a-1c illustrate three views of a finned helicoidal heat exchanger with plane straight fin;

Figures 2a-2d illustrate alternative embodiments of the fins attached to the helicoidal tube;

Figures 3a-3c illustrate the finned helicoidal heat exchanger with folded fins;

Figure 4 illustrates alternative embodiments of tube cross sections;

Figures 5a-5c illustrate a finned helicoidal heat exchanger with a rectangular cross section tube;

Figure 6 illustrates a tube cross-section having microchannels

Figure 7 illustrates in a top view alternative embodiments of the helicoidal heat exchanger;

Figures 8a-8d illustrate a finned helicoidal heat exchanger having a blower; and

Figures 9a-9b illustrate two alternative arrangements of a multi-coil finned helicoidal heat exchanger.

Detailed Description of the Preferred Embodiments

The embodiments disclosed below are not intended to be exhaustive or limit the invention to the precise forms disclosed below. Rather, the embodiments are chosen and described so that others skilled in the art may utilize their teachings.

Referring to the accompanying drawings in which like reference numbers indicate like elements, Figures 1a-1c illustrate a finned helicoidal heat exchanger 20. The helicoidal heat exchanger 20 includes a heat transfer tube 22 arranged substantially in the shape of a continuous helicoidal tube. The helicoidal heat exchanger 20 also includes a fin 21 secured to the external surfaces of the heat transfer tube 22. Figures 1a-1c illustrate an embodiment having a plurality of evenly spaced fins 21A, 21B secured to the external surfaces of the heat transfer tube 22 and extending outwardly therefrom. The heat transfer tube 22 has a pitch. The pitch of a helical or helicoidal shape is generally defined as the distance from any point on the loop of a helix thread or strand to the corresponding point on the next adjacent loop of the same thread or strand, measured parallel to the axis and on the same side of the axis.

A helix can be a single thread (as illustrated in Figures 1-3 or as in U.S. Patent No. 1,785,159) or can be a double strand helix (as illustrated in Figure 9 or as in a DNA strand) or it can be a multi strand helix. The strands may be placed in line where the inside strand and outside strand have the same pitch and have the same tube diameter but the inner strand has smaller coil diameter compared to the outer strand. In this inline arrangement, the each individual loop of the inner strand and the corresponding loop of the outer strand are essentially in a horizontal plane as shown in Figure 9b. The strands may also be arranged inline in a vertical plane as shown in Figure 9a. The strands may also be arranged in a staggered arrangements, in-between the above two limits, where the strands (two or more) may have different pitch, different coil and tube diameters.

In the present invention, each of the heat exchanger tubes or each strand is a continuous conduit formed in a helicoidal shape with a number of adjacent loops (22A, 24A, & 32A, 32B & 42A, 42B, & 22A, 22B). Each loop is connected to some or all the other loops through the fins. In the preferred embodiment, each loop has an interval space (22C, 32C, 42C) with the adjacent loop, regardless whether there is a single or multiple strands in the helix. However, for the present invention, there does not need to be a space between adjacent loops, i.e., each tube section could actually be in contact with the other adjacent tube sections as well as being connected by the fins.

While in the depicted embodiment of Figures 1a-1c illustrate a single strand or heat transfer tube 22, some embodiments may have more than one heat transfer tube. For example, the finned heat exchanger 20 may include several individual helicoidal strands running parallel to one another in a spiral pattern as shown in Figures 9a and 9b. Each fin 21 includes a plurality of openings 23 corresponding to the number of loops in tube 22. The tube 22 passes through the fins' openings 23. While in the depicted embodiment the openings are through-holes, depending on the application and tube cross section, they may also be slots, grooves or notches. The fins 21 are connected to the tube 22 and may be affixed to the tube 22 such as by welding, soldering, brazing, chemically attaching, or by expanding the tubes 22 using a variety of commonly used methods. A first working fluid flows inside the heat transfer tube 22, and a second working fluid, typically air, flows through a passage defined by the adjacent fins 21 and the tube 22. For example, the air may flow radially, axially or a combination of the two through the passage.

The fins 21 can be plain as shown in the example of Figures 1a-1c. They can also assume the configuration of the any of the commonly used types in heat exchangers such as

perforated, louvered, slotted, wavy, spine etc. The fins 21 can be continuous as shown in Figures 1a-2c, or can be segmented as shown in Figure 2d where fin segments 21' are attached to the helicoidal tubes at an arbitrary angle 28 relative to the tube 22. Some or all of the fin segments 21' may connect with one another to form continuous fins 21 or may be left segmented.

The tube outer surface can also be plain as shown in the examples of Figures 1a – 2d or can also be formed in the configuration of the any of the commonly employed tube enhancements methods such as grooved or dimpled. The inside surface of the tube can also be plain or altered using any of the commonly used methods to enhance the inside rate of heat transfer such as grooved, dimpled, or inserting twisted tape turbulators.

Figures 3a-3c show three views of a helicoidal heat exchanger having a tube 32 and enhanced with folded fins 31. The folded fins 31 are formed by folding a first sheet of a heat conductive material back and forth on itself to provide accordion-like folds. The folded fins 31 have openings, such as slots or holes, cut through them at the folds or below to allow the fins to fit onto the tubes and be attached to the tubes 32 using any one of the aforementioned methods. The embodiments of Figures 3a-3c can further be modified by replacing the triangular pattern of fins with rectangular, or other fin arrangement profiles. The fins shown in Figures 3 are continuous. They can also be segmented, i.e. the fins may be cut along their fold line, similar to the fins shown in Figure 2d, which can then be arranged between the adjacent loops in any pattern.

Another category of modifications is the changing of the shape of the tube cross-section. The tubes shown in Figures 1a –3c have circular cross sections. Other tube cross sections, typically used in heat exchanger manufacturing like flat tubes, lenticular, square, rectangular, triangular, or elliptical channels or any other cross section, some of which are

shown in Figure 4, can replace the tubes shown in the drawings. For example, the tube may be circular 40A, lenticular 40B, elliptical 40C, square 40D, rectangular 40E, or triangular 40F.

Figures 5a-5c show a helicoidally finned heat exchanger made with a helicoidal pipe 42 having rectangular cross section and enhanced with fanfold fins 31. In the depicted embodiment, the helicoidal pipe 42 forms a first winding and the fins 31 form a second winding. As stated above, the fin arrangement shown is one of the many that can be used.

Another embodiment is a finned helicoidal microchannel heat exchanger. Microchannel heat exchangers use channel widths of 10 to 1,000 μm. In microchannel heat exchangers the heat transfer coefficients are very high and therefore relatively short flow passages are required, causing the pressure drop to be small. The small size of the individual channels allow the placement of many flow passages in parallel in a small device. Figure 6, shows the cross section of the pipe 42 of the finned helicoidal microchannel heat exchanger as shown in Figure 5. The cross-section illustrates the microchannels 60. Again, the microchannels do not need to be circular, and can have any cross sections, including those shown in Figure 4. They also can be arranged in a parallel horizontal arrangement as shown in Figure 7, or in a vertical arrangement of in a staggered manner anywhere in between.

As shown in Figures 1c, 3c, and 5c the top view of all the above embodiments of the invention is a circle since the helical coils are formed in that shape. The circular coil shape represents one of the possible configurations and the invention is not limited to just the circular cross section as the coil cross section can be in any other form, as some additional possibilities are shown in Figure 7. For example, the coil shape may be rectangular 70A, elliptical 70B, or triangular 70C.

Another improvement made to the helicoidally finned heat exchangers is the

incorporation of a blower 51, shown in Figures 8a-8d. The blower 51 can either be placed in the hollow core 25 as shown in Figure 8c or around the outside of the coil as shown in Figure 8d. Addition of the blower enhances the velocity of the second heat exchanging fluid and thus the overall rate of heat transfer, without requiring much extra space. Hence, the second working fluid can be forced by the blower axially along the fins or radially in the core 25 or a combination of the two.

Figures 9a and 9b show two configurations of a double pipe (strand) helicoidal heat exchanger. In the embodiment of Figure 9a, the fins are removed to show its essential features. In a pipe, two helicoidal coils, 22 and 24 run parallel to one another. The number of parallel coils can be as many as required and the arrangements are not limited to the two shown. In Figure 9a, the tubes (strands) 22A and 24A have the same coil diameter and the same pitch, although they don't have to have the same tube diameter and are intertwined, and arranged in the same vertical plane. In Figure 9b, the tubes (strands) 24B have different coil diameters, i.e. strand 24A has a smaller coil diameter than tube 22B. In the case shown in Figure 9b, the strands have the same pitch and therefore the loops are in line, or essentially on the same plane which is almost horizontal. The other embodiments include multiple coils that have different coil and/or tube diameters or pitch that are arranged in staggered and/or inline arrangement. The tubes 22, 24 are operatively connected by a header 26.

Referring to Figure 1a, in operation, a first working fluid (not shown) flows into the tube 22 at an inlet. The first working fluid flows through the tube 22 and heats (or cools) the tube 22 and the fins 21. A second working fluid (not shown), air for example, flows over and between the fins 21 to cool (heat) the fins and the tubes and therefore the first fluid. If the first working fluid is the warmer fluid, the heat will be transferred from the inner wall towards the outer wall of the tube 22. The fins 21 conduct heat away from the outer surface

of tube 22 and transfer the heat to the second working fluid. For increased efficiency, the second working fluid may be forced over and between the fins 21. In the depicted embodiment of Fig. 8C, a blower apparatus forces the second working fluid from a central axis of the tube outwardly and past the fins 21. The first working fluid cools as it flows through the tube 22. The first working fluids exits the tube 22 at an outlet.

In view of the foregoing, it will be seen that the several advantages of the invention are achieved and attained. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated.

As various modifications could be made in the constructions and methods herein described and illustrated without departing from the scope of the invention, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative rather than limiting. For example, while the cross-section of the helicoidal tube is shown as circular, the cross-section could also be a flat tube, lenticular, square, rectangular, triangular, or elliptical. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims appended hereto and their equivalents.